Technology Opportunity

Glenn Research Center • Cleveland • Ohio

Technology Transfer & Partnership Office

TOP3–00203

CARES/*Life* Software Tool for Characterizing and Predicting the Structural Integrity of Microelectromechanical (MEMS) Devices

Technology

The Life Prediction Branch of the NASA Glenn Research Center has been a pioneer and world leader in brittle-material design methodology development over the past two decades. A direct result of this work has been the development of the CARES/*Life* (Ceramic Analysis and Reliability Evaluation of Structures/Life prediction) software that characterizes and predicts the integrity of brittle material structures. It is hereby proposed to leverage this expertise and software base to develop and make available to industry a version of CARES/*Life* optimized for MEMS device durability assessment.

Benefits

- Quantifies the inherent wide dispersions (scatter) in strengths introduced by etching-induced pits and edge flaws
- Enables part integrity assessment prior to manufacture
- Enables reliability to be tracked as a function of the part's time in service under sustained and repeated loadings
- Enables rapid prototyping of a design before the actual hardware is produced

Commercial Applications

CARES/*Life* is already a successful and widely recognized program used by hundreds of organizations worldwide. It has won a NASA Software of the Year Award, an R&D 100 award, and a Federal Laboratory Consortium Award (technology transfer). Some organizations have already requested this program for MEMS-specific applications, including sensor arrays for spacecraft, piezoelectric ceramic sticks for inkjet print heads, and microturbine development. CARES/*Life* is suitable for MEMS reliability evaluation of brittle materials and is currently used for polycrystalline (isotropic) materials. It is the most useful for harsh environment applications that challenge the capabilities of existing materials.

Technology Description

MEMS devices are typically made from brittle materials, such as silicon, and are manufactured using techniques borrowed from the semiconductor industry, which usually involve sacrificial etching of material. By-products of etching—pits, microcracks,

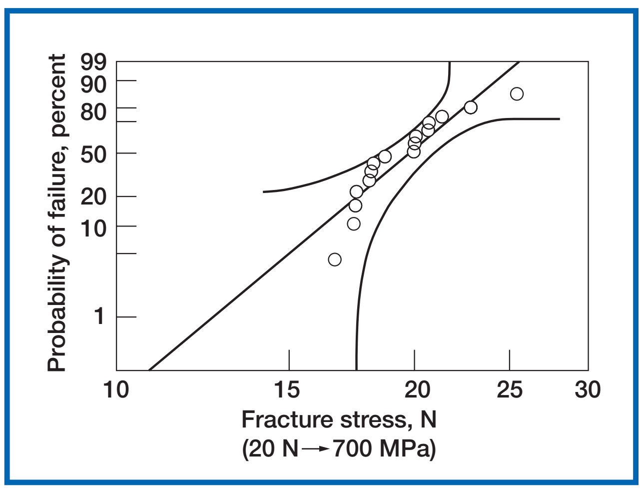

Figure 1.—Rupture of plasma-etched silicon specimens illustrating variability in part strength. Fast-fracture data from least-squares analysis; Weibull modulus, m, 9.302; characteristic strength where 63.21 percent of specimens fail, σ_θ, 20.6 N; temperature, 25.00 °C.

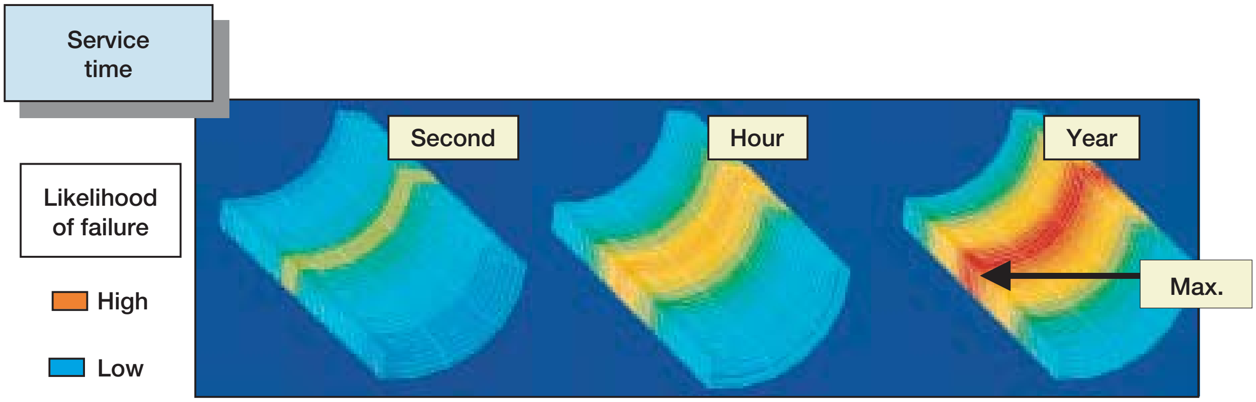

Figure 2.—Risk-of-rupture intensity map from CARES/Life showing damage evolution as a function of time in service for a thermally loaded and pressurized tube.

or chips along edges and on surfaces—act as stress concentrators that weaken the part (fig. 1). The random size of these flaws, coupled with the brittle nature of the material, results in widely varying strength from part to part.

Furthermore, because these devices may be operating in a hostile environment (hostile with regards to temperature or because the ambient environment is chemically active), they are also susceptible to slow crack growth. Therefore, not only is the strength of the device random in nature, but this strength can degrade with time or cyclic loading.

The CARES/*Life* design methodology combines the statistical nature of strength-controlling flaws with the mechanics of crack growth to predict the probability that a brittle material component will fail as a function of its time in service (fig. 2). This methodology accounts for multiaxial stress states, concurrent (simultaneously occurring) flaw populations, slow crack growth, proof testing, and component size and scaling effects. CARES/*Life* interfaces with commercially available finite element software such as ANSYS or ABAQUS. It can also use test data from specimen rupture tests to obtain the statistical (Weibull) and fatigue parameters required for device life assessment. With this type of integrated design tool, a design engineer can make appropriate design modifications until an acceptable probability of failure is achieved, or until the design has been optimized with respect to some variable design parameter.

Further MEMS-specific enhancements proposed for CARES/*Life* include single-crystal reliability analysis, edge-flaw recognition and modeling, and an MEMS materials database.

Options for Commercialization

The NASA Glenn Research Center continually seeks cooperative partnerships with industry, government, and academia to develop new brittle-material life-prediction capabilities, further enhance existing technology, and provide valuable exchange of information on current structural ceramics research activities. The CARES series of software and the expertise of the developers are available to all interested organizations. You can obtain the CARES software from the NASA Glenn Research Center Software Repository (SR) at https://www.technology.grc.nasa.gov/software.

Contact

Technology Transfer & Partnership Office
NASA John H. Glenn Research Center
at Lewis Field, Mail Stop 4–2
Cleveland, OH 44135–3191
Phone: 216–433–3484, Fax: 216–433–5012
E-mail: ttp@grc.nasa.gov
http://technology.grc.nasa.gov

References

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Key Words

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